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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re United States Patent Application of:		**Docket No.:**	**2771-546-CIP1**
Applicants:	**DIMEO JR., Frank, et al.**	**Conf. No.:**	**8335**
Application No.:	**10/784,606**	**Art Unit:**	**2856**
Date Filed:	**February 23, 2004**	**Examiner:**	**Jacques M. Saint Surin**
Title:	**NICKEL-COATED FREE-STANDING SILICON CARBIDE STRUCTURE FOR SENSING FLUORO OR HALOGEN SPECIES IN SEMICONDUCTOR PROCESSING SYSTEMS, AND PROCESSES OF MAKING SAME**	**Customer No.:**	**23448**

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May 2, 2007

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(Use as many sheets as necessary)

Complete if Known	
Application Number	10/784,606
Filing Date	2/23/2004
First Named Inventor	Dimeo Jr. et al.
Art Unit	2856
Examiner Name	Jacques M. Saint Surin
Attorney Docket Number	2771-546-CIP1

Sheet	1	of	2

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number: Number - Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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Examiner Initials*	Cite No.[1]	Foreign Patent Document: Country Code[3] - Number[4] - Kind Code[5] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

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	CT	VAN ZANT, PETER, Chapter 8: The ten-step patterning process -- Surface preparation to exposure, Microchip Fabrication: A Practical Guide to Semiconductor Processing, 5th Ed., 2004, Page(s) 197-203, Publisher: McGraw-Hill, Published in: New York, NY	

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Microchip Fabrication

A Practical Guide to Semiconductor Processing

Peter Van Zant

Fifth Edition

McGraw-Hill
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Mexico City Milan New Delhi San Juan Seoul
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Chapter

8

The Ten-Step Patterning Process—Surface Preparation to Exposure

Overview

Patterning is the series of processes that establishes the shapes, dimensions, and placement of the required physical "parts" (components) of the IC in and on the wafer surface layers. This chapter presents the first four steps of a basic ten-step photo process and a discussion of photoresist chemistry.

Objectives

Upon completion of this chapter, you should be able to:

1. Sketch wafer cross sections showing the basic ten-step photomasking process.
2. Explain the reaction of negative and positive photoresists to light.
3. Describe the correct resist and mask polarities required to produce holes and islands in wafer surface layers.
4. Make a list of the major process options for each of the ten basic [illegible]
5. [illegible] from the list in objective 4 the processes used to pattern features [illegible] micron and submicron sizes.
6. [illegible] the need for, and process steps used in, double masking, multilayer resist processing, and planarization techniques.
7. [illegible] the use of antireflective coatings and contrast enhance-[illegible] the patterning of "small" feature sizes.

8. List the optical and nonoptical methods used for alignment and exposure.
9. Compare the equipment and advantages of each alignment and exposure method.

Introduction

Patterning is one of the basic operations. At the end of the operation, a surface layer is left with either a hole or an island. (See Fig. 8.1.) *Patterning* is also called *photolithography, photomasking, masking, oxide removal* (OR)), *metal removal* (MR), and *microlithography.*

Patterning is one of the most critical operations in semiconductor processing. It is the process that sets the surface (horizontal) dimensions on the various parts of the devices and circuits. The goal of the operation is twofold. First is to create, in and on the wafer surface, a pattern with the dimensions established in the design phase of the IC or device. This goal is referred to as the *resolution* of the images on the wafer.

The second goal is the correct placement of the circuit pattern on the wafer. The entire circuit pattern must be correctly placed on the wafer surface relative to the crystal pattern of the wafer substrate, and the individual parts of the circuit must line up relative to each other (Fig. 8.2). This is called *alignment* or *registration* of the various circuit patterns. A typical IC requires 20 to 40 individual patterning (or masking) steps. This registration requirement is similar to the correct alignment of the different floors of a building. It is easy to visualize that misalignment of elevator shafts and stair wells would render the building useless. In a circuit, the effects of misaligned mask layers can cause the entire circuit to fail.

Control of the dimensions and defect levels is difficult, because each step in the patterning process contributes variations. A patterning

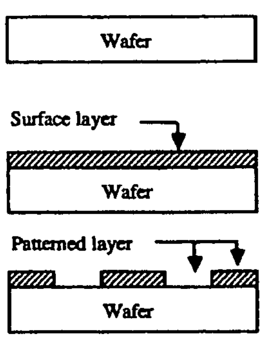
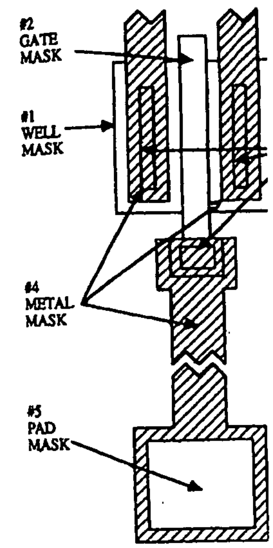


Figure 8.1 Basic patterning process.



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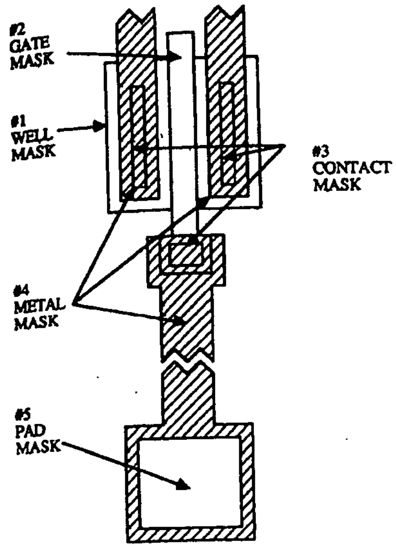


Figure 8.2 Five mask set silicon gate transistor.

process is one of trade-offs and balancing (see sections on individual patterning processes). In addition to dimensional control and pattern alignment, defect control during the process steps is critical. Given the number of steps in each patterning operation and the number of mask layers, the masking process is the chief source of defects.

Overview of the Photomasking Process

Photolithography is a multistep pattern transfer process similar to photography and stenciling. The required pattern is first formed in reticles or photomasks and transferred into the surface layer(s) of the wafer through the photomasking steps.

The transfer takes place in two steps. First, the pattern on the reticle or mask is transferred into a layer of photoresist (Fig. 8.3). Photoresist is a light-sensitive material similar to the coating on a regular photographic film. Exposure to light causes changes in its structure and properties. In the example in Fig. 8.3, the photoresist in the region exposed to the light was changed from a soluble condition to an insoluble one. Resists of this type are called *negatively acting,* and the chemical change is called *polymerization.* Removing the soluble portion with chemical solvents (developers) leaves a hole in the resist layer that corresponds to the opaque pattern on the reticle.

The second transfer takes place from the photoresist layer into the wafer surface layer (Fig. 8.4). The transfer occurs when etchants re-

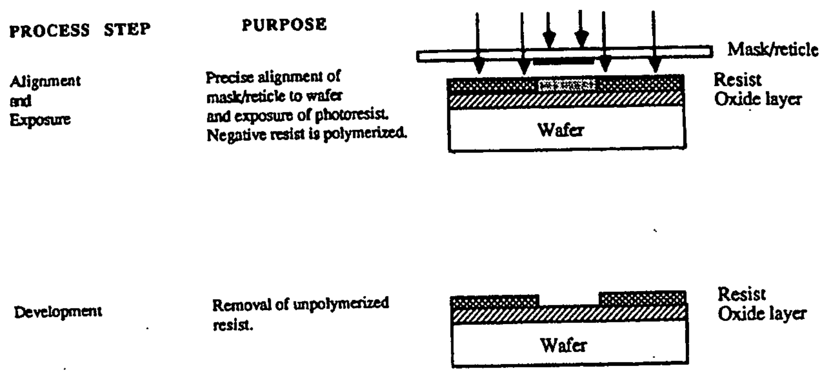


Figure 8.3 First pattern transfer—mask/reticle to resist layer.

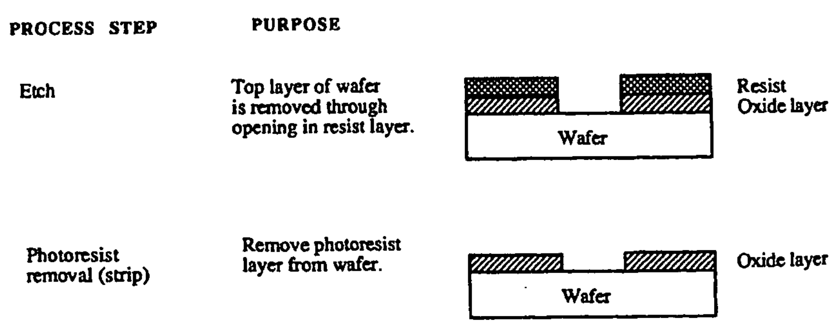
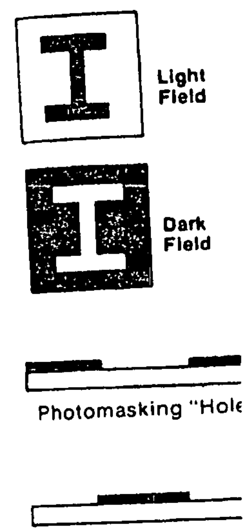


Figure 8.4 Second pattern transfer—resist layer to surface layer.

move the portion of the wafer's top layer that is not covered by the photoresist. The chemistry of photoresists is such that they do not dissolve (or dissolve slowly) in the chemical etching solutions; they are *etch-resistant,* hence the name *resists* or *photoresists*.

In the examples shown in Figs. 8.3 and 8.4, the result is a hole etched in the wafer layer. The hole came about because the pattern in the mask was opaque to the exposing light. A mask whose pattern exists in the opaque regions is called a *clear-field mask* (Fig. 8.5). The pattern could also be coded in the mask in the reverse, in a dark-field mask. If the same steps were followed, the result of the process would be an island of material left on the wafer surface (Fig. 8.6).

The resist reaction to light just described is a character of negative-acting photo resists. There are also positive-acting photo resists. Within these resists, the light changes the chemical structure from relatively nonsoluble to much more soluble. The term describing this



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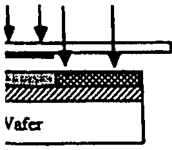

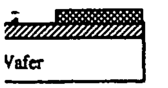

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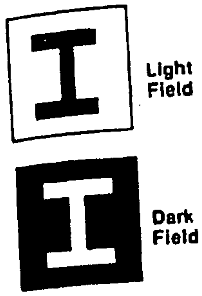


Figure 8.5 Mask-reticle polarities.

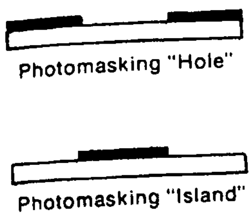


Figure 8.6 Photomasking hole and island.

change is *photosolubilization*. Figure 8.7 shows that an island is produced when a light-field mask is used with a positive photoresist.

The result obtained from the photomasking process from different combinations of mask and resist polarities is shown in Fig. 8.8. The choice of mask and resist polarity is a function of the level of dimensional control and defect protection required to make the circuit work. These issues are discussed in the process sections of the chapter.

Ten-Step Process

Transferring the image from the reticle or mask onto the wafer surface layer is a multistep procedure (Fig. 8.9). Feature size, alignment tolerance, the wafer surface, and the masking layer number all influence the difficulty and steps for a particular masking process. Many photo processes are customized to the particular conditions. However, most are variations or options of a basic ten-step process. The process illustrated is shown with a light-field mask and a negative photoresist.

The first image transfer takes place in steps 1 through 7. In steps 8, 9, and 10, the image is transferred (second image transfer) into the wafer surface layer. The reader is challenged to list the steps and draw the corresponding cross sections using combinations of a dark field mask and a positive photoresist. It is strongly recommended that the reader master this ten-step process before proceeding to the advanced photolithography processes.

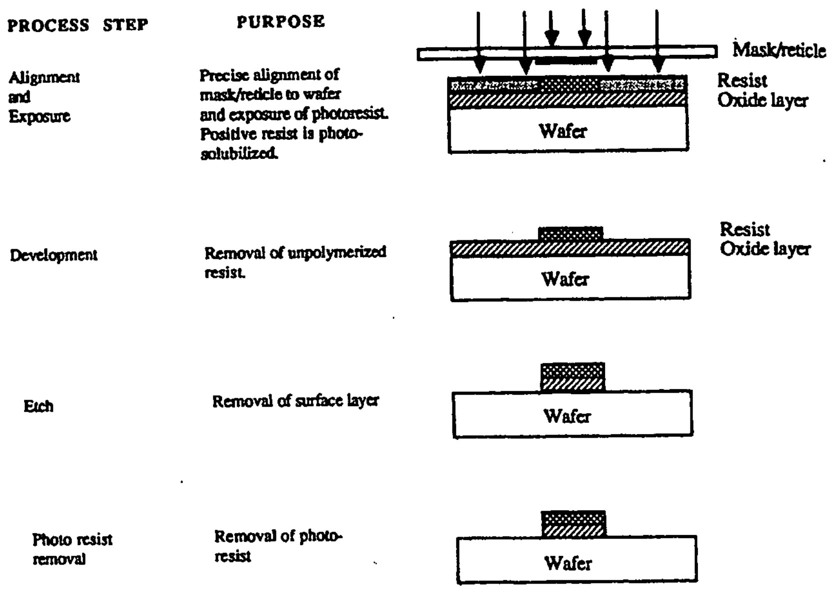


Figure 8.7 Image transfer from a light-field mask with a positive photoresist to create an island.

		Photoresist Polarity: Negative	Photoresist Polarity: Positive
MASK POLARITY	Clear Field	HOLE	ISLAND
	Dark Field	ISLAND	HOLE

Figure 8.8 Mask and photoresist polarity results.

Basic Photoresist Chemistry

Photoresists have been used in the printing industry for over a century. In the 1920s, they found wide application in the printed circuit board industry. The semiconductor industry adapted this technology to wafer fabrication in the 1950s. Negative and positive photoresists designed for semiconductor use were introduced by Eastman Kodak and the Shipley Company, respectively, in the late 1950s.

The photoresist is the heart of the masking process. The preparation, bake, exposure, etch, and removal processes are fine-tuned to ac-

PROCESS STEP	PURPOSE
1. Surface Preparation	Clean and dry wafer surface
2. Photoresist apply	Spin coat a thin layer of photoresist on surface
3. Softbake	Partial evaporation of photoresist solvents by heating
4. Alignment and Exposure	Precise alignment of mask/reticle to wafer and exposure of photoresist. Negative resist is polymerized.
5. Development	Removal of unpolymerized resist.
6. Hard bake	Additional evaporation of solvents
7. Develop inspect	Inspect surface for alignment and defects
8. Etch	Top layer of wafer is removed through opening in resist layer.
9. Photoresist removal (strip)	Remove photoresist layer from wafer.
10. Final inspection	Surface inspection for etch irregularities and other problems

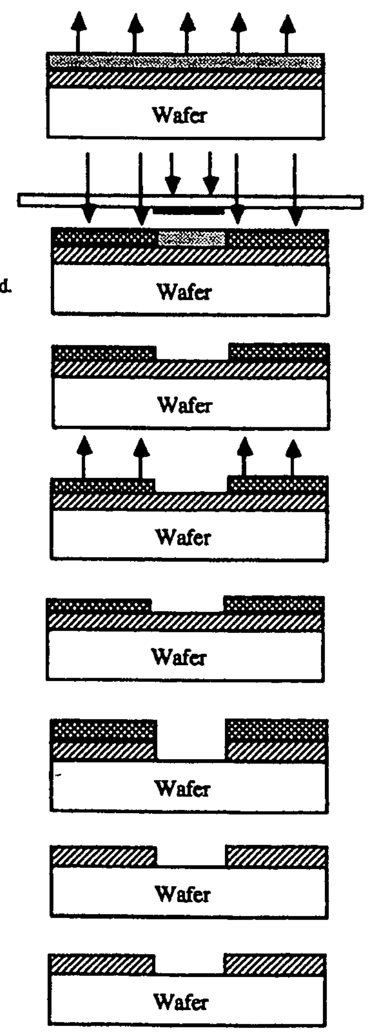
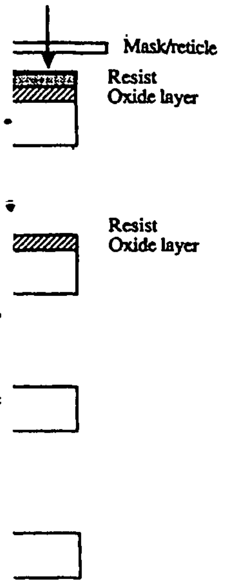


Figure 8.9 Ten-step photomasking process.



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